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Initial progress is reported for year 1 of a 3-year project to investigate the transmission ecology of tick-borne Crimean-Congo Hemorraghic Fever virus (CCHFV) in the West African savannah. Long-term, prospective observations were begun a 3 sites in northern Senegal; other studie of virus and tick prevalence include Mauritania and The Gambia. Vertebrates and ticks were catalogued and components of their ecology described. At least 8 Ixodid tick species were identified including **Hyalomma marginatum rufipes** and **H.truncatum**. Initial results from more than 400 birds (42 species) and 500 small mammals (8 species) indicate these immature ticks are most active from August to october. Observations from 1,500 domestic ungulates demonstrate a more diffuse pattern for adults. Estimates of vertebrate density and host association are being made The temporal pattern of "drop-off" of adult and larval **H.truncatum** appears non-uniform. Studies of the reproductive capacity of numerous **Hyalomma** species have begun. Studies of virus transmission in nature include measuring IgG antibody prevalence in vertebrates and infection rates in vectors to develop estimates of transmission frequencies between ticks stages or ticks and hosts.

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ECOLOGY AND EPIDEMIOLOGY OF CRIMEAN-CONGO HEMORRHAGIC FEVER VIRUS TRANSMISSION IN THE REPUBLIC OF SENEGAL

ANNUAL REPORT

Mark L. Wilson and Jean-Pierre Digoutte

March 1988

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SUMMARY

The recognized distribution of Crimean-Congo Hemorragic Fever (CCHF), a life-threatening tick-borne viral zoonosis, has recently expanded to include southern U.S.S.R, central Asia, southern Europe, the Middle East, and the entire African continent. At least 28 Ixodid tick species, most notably of the genus *Hyalomma*, have been found to be infected by CCHF virus (CCHFV); their importance in maintaining transmission in nature, however, is poorly understood. Various species of mammals exhibit CCHFV antibodies, yet their role in horizontal transmission or amplification of the virus remains undefined. Following reports of CCHFV transmission and isolation in Senegal and Mauritania, systematic observations were initiated in order to describe important components of the transmission cycle in nature.

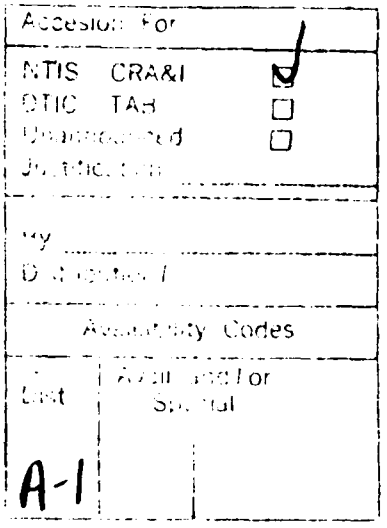
During the first year of this proposed three year project, we cataloged the most prominent vertebrates and ticks indigenous to northern Senegal, the principal region of study. Prospective longitudinal analysis of the tick and vertebrate fauna at 3 sites was begun and continues throughout the entire cycle of seasons. At least 8 tick species have been identified, including *H. marginatum rufipes* and *H. truncatum*, both believed to be important vectors of CCHFV. To study immature ticks we have examined about 400 birds comprising over 40 species; a similar number of small mammals has been examined from among 8 species including the genera *Mastomys*, *Arvicanthis*, and *Taterillus*, which are considered candidate reservoirs. Domestic ungulates are being sampled regularly in studies of adult tick seasonal activity, density and host associations; more than 1,500 cattle and sheep have been thusly examined. In laboratory studies involving the temporal pattern of detachment of *H. truncatum*, we have preliminary results demonstrating a diurnal pattern of drop-off of larvae from guinea pigs and of adults from sheep. Studies of the reproductive capacity of many *Hyalomma* species are underway in a attempt to begin demographic analyses of these ticks.

Investigations of the natural cycle of CCHF virus transmission involve studies of infection rates in vertebrates and ticks, and estimates of transmission frequencies between tick stages or ticks and their hosts. Blood samples from more than 800 sheep and cattle are being tested to determine infection rates; individually identified sheep are being followed to calculate CCHFV infection incidence. More than 10,000 ticks have thusfar been collected to estimate minimum field infection rates for each species. Engorged ticks removed from natural hosts are being held until egg-laying occurs; eggs are then tested for transovarial transmission of CCHFV. These observations are being synthesized using simple mathematical models that may be employed to formulate strategies for interrupting transmission.

FOREWORD

Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

In conducting the research described in this report, the investigators adhered to the "Guide for the Care and Use of Laboratory Animals" prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Institute of Laboratory Animal Resources, National Research Council (DHEW Publication No. (NIH) 86-23, Revised 1985).



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INTRODUCTION

Crimean-Congo Hemorrhagic Fever (CCHF), is one of a group of arthropod-borne viral zoonoses producing acute, sometimes fatal febrile and hemorrhagic disease. Symptoms initially involve the nervous system, and in severe cases progress to vascular disorders such as profuse diapedetic hemorrhages, brain edema, general malaise, and ultimately cardiac arrest. Human disease was first recognized from the Crimea, U.S.S.R. in 1945 (Chumakov 1945, 1947); shortly thereafter the viral agent was isolated from ticks (reviewd by Chumakov 1974). Crimean-Congo Hemorrhagic Fever virus (CCHFV), family Bunyaviridae, genus Nairovirus, was later found to be identical to that of "Congo virus" from Africa (Casals, 1969).

The recognized distribution of CCHF has recently expanded to include southern U.S.S.R, central Asia, southern Europe, the Middle East, and the entire African continent (Hoogstraal, 1979; Watts et al., in press). In West Africa, Senegal and southern Mauritania have received attention as locations where CCHFV infects certain vertebrate and tick species. Initial observations by Chunikhin et al. (1969(a)) demonstrated evidence of domestic animal infections in particular vegetational-climatic zones of Senegal. Later, ticks from a Dakar, Senegal abattoir were studied and numerous strains of CCHFV were isolated (Robin & Le Gonidec 1972, Robin 1972, 1973, 1974, 1975). Similar recent observations of human and domestic animal sera identified other foci of transmission in various regions of Senegal and along the border with Mauritania. (Saluzzo et al. 1984, 1985(a), 1985(b), 1986, Camicas et al. 1986). Thus, foci of CCHFV infection have existed in this region for at least 2 decades; whether these foci persist with a low level of enzootic transmission, periodically erupt in epizootics, or are regularly reestablished by migrating reservoirs remains unknown.

Although at least 28 species of Ixodid ticks have been shown to be capable of supporting infection by CCHF virus, the role played by these ticks in maintaining the transmission cycle in nature has not been clearly defined. Most epidemiological reports seem to implicate certain *Hyalomma* species which differ with geographic region. *H. marginatum rufipes* is often associated with intense transmission in western Africa (Hoogstraal, 1979). This association, however, is based upon sparse evidence of naturally aquired tick infection, combined with information on ecological associations among adult ticks. Surprisingly little is known about the ecology, population dynamics and host-associations of immature *Hyalomma* species. No vertebrates have yet been demonstrated to serve as maintenance reservoirs of the virus, although circumstantially, particular species are suspect. Transovarial transmission of the virus between tick generations can occur, but its importance in nature relative

to that of horizontal transmission is not known. Although we have information concerning certain individual components of the natural cycle of CCHFV, the manner in which these variables interact to maintain transmission is poorly understood. Accordingly, the long-term goals of this project are to investigate further those variables that are inadequately defined and most likely to be important in the transmission cycle of CCHFV, and to integrate these new observations with existing knowledge in an attempt to develop a complex model capable of describing the enzootic cycle and the epidemiology of human disease. This report summarizes accomplishments during the first year of a projected three year effort.

Objectives

The objectives of the first year of this project include:

1. Survey various sites in northern Senegal to establish the feasibility of long-term study.
2. Confirm the presence of abundant vector tick populations and virus activity.
3. Describe prominant geographic, vegetational and climatic features of each site.
4. Commence longitudinal field observations of tick-host associations and seasonal patterns of tick abundance.
5. Begin long-term study of temporal and spatial distribution of CCHFV infection in domestic and wild vertebrate and tick populations.

Other studies, such as laboratory observations on transmission using natural hosts, human infection rates and analysis of risk factors, are planned for the second and third years of this project.

The studies described in this document are being undertaken by a team of investigators comprised of scientists, and technicians from numerous institutions. The effort is one of collaboration, involving ecologists, entomologists, immunologists, epidemiologists, and virologists. Persons who have contributed to the project during its first year are listed in Table 1.

Site Selection and Preliminary Observations

Initial selection of potential long-term field sites was based upon information from recent studies undertaken at the Institut Pasteur (Camicas et al. 1986, Saluzzo et al. 1985(a) and unpublished data). Various sites were visited and the logistics and technical feasibility of extensive observations were evaluated. We considered factors such as: 1) the abundance and diversity of wild and domestic vertebrates and

the migratory patterns of such domestic animals, 2) the relative abundance of ticks, in particular, *Hyalomma* species, in these areas, 3) evidence of past or present CCHFV circulation, and 4) probability of human contact and exposure, and willingness of local residents to cooperate in serosurvey studies.

Based upon this information, we identified 3 principal study sites which would serve as long-term, intensive centers of research. Two of these sites are represented by the villages of Yonofere and Dahra, located in northern-central Senegal in the middle of a vast region of sparsely inhabited grassland and shrubland designated the "Ferlo" (Fig. 1). The third site, in the village of Bandia, is located further to the west, near the Atlantic coast southeast of Dakar.

Yonofere is a small village of perhaps 1,000 year-round inhabitants occupying a few hundred widely dispersed huts about 300 km (ca. 7 hours by vehicule) to the east-northeast of Dakar (Fig. 1). The region is classified as Sahelo-sudanian savannah, a dry "thorn-brush" habitat dominated by grasses and widely dispersed trees, particularly *Acacia* spp. (Barral 1982). Rainfall occurs principally during July through September and may vary considerably from year to year, averaging about 500 mm annually. Residents grow millet during the rainy season and herd sheep, goats and cattle year-round. During the later part of the dry season, these animals may be moved 10-30 km during each day in search of food, returning for the night to obtain water. In addition to these permanent residents, the site is annually visited by migrating herdspeople that move thousands of domestic ungulates through the region seeking forage. These people drive their cattle, camels, sheep and goats southward during the dry season and again northward each year when the rains recommence. Because of the large government-owned, diesel-powered water well located in the village center, Yonofere abounds with resident and migratory domestic and wild vertebrates.

The second site, in the village of Dahra, lies about 100 km west of Yonofere and 200 km east-northeast of Dakar (Fig. 1). The habitat, rainfal and geo-climatic characteristics are similar to those of Yonofere. In Dahra, however, we are studying two different but comparable sites: one inside a national research station for domestic animal husbandry (designated Dahra-station, and another outside that station where cooperating resident herdspeople provide us access to their animals and land (desinated Dahra-village). Although climate and habitats are similar to that found in Yonofere, animal density and movement differ both inside and outside the research station. Senegal's "Institut Scientifique de Recherche Agricola" (ISRA) field station, under the direction of the Laboratoire National de l'Elevage et de Recherches Veterinaires, maintains about 600 cattle and 400 sheep on roughly 6,800 ha of improved pasturage. A variety of research

projects require periodic observations of the individually-tagged ungulates that are confined within the fences that surround the field station. In all other respects, these animals are similar to those found outside the station, except that they are maintained at a lower average density. Privately-owned cattle and sheep in Dahra-village are treated similarly to those at the the Yonofere site.

The third site, in the village of Bandia, is located about 20 km from the Atlantic coast, some 60 km. southeast of Dakar. On the edge of the Bandia forest, this more heavily vegetated region receives somewhat greater average rainfall (ca. 700 mm); fluctuations in both daily and seasonal temperatures are somewhat modulated by the proximity to the ocean. Herds of cattle, goats and sheep pass through the area, but most of our research on domestic animals is carried out on sentinel cows and goats. This station has been the site of numerous previous studies of mammals (e.g. Hubert 1977), arthropod vectors (Camicas et al. 1970), and virus isolation (e.g. Digoutte 1985), and thus offers an extensive history of observations for comparison.

In addition to these three long-term study sites, observations are occasionally made at various sites throughout the country, including the Dakar abattoir, the region of Kedougou, and the Sine Saloum and Senegal River basins. By definition, this report describes past progress of continuing research; methods are described in the active present tense. Results are reported for the first 12 months of study which ended 31 December, 1987. Analysis of much of the data already collected is not yet complete, therefore some results are presented in a qualitative form.

The remainder of this document is organized by topical questions divided into three groups: 1) tick ecology and behavior, 2) vertebrate-virus interactions and 3) virus transmission. A summary of activities during the year, in relation to those planned in the proposal, is provided as Table 2.

I. TICK ECOLOGY and BEHAVIOR

Host Associations, Densities, and Seasonal Activity

A major objective of our study is to determine which species of tick(s) and vertebrate(s) are important in CCHFV transmission. The viral agent of CCHF is exceptional among zoonotic arboviruses in the number and ecological diversity of potential vectors and vertebrate hosts with which it is associated, as well as the variety of faunal regions (Afrotropical, Palearctic and Oriental) in which it occurs. Previous studies have implicated various 2-host or 3-host African ticks, either by inference or evidence of infection (reviewed by Hoogstraal 1979); these include 6 species of the genus *Hyalomma*, and one each of the genera *Amblyomma* and *Rhipicephalus*. Among our study sites, 4 of the *Hyalomma* species and *Amblyomma variegatum* are present. The hosts on which these ticks naturally feed represent the vertebrates which may serve as reservoirs in the CCHFV cycle. All of these Ixodid ticks principally feed upon ungulates as adults, and they are abundant on the domestic ovids and bovines under study. Immature ticks are being studied through observations of wild birds and small mammals, their principal hosts.

In order to characterize the temporal, spatial and ecological patterns of activity and population density of these ticks and their hosts, we have begun various long-term observations at the 3 major study sites; we intend that these observations will be continued for at least the next 18 months. Studies described below are being undertaken in collaboration with Drs. Jean-Paul Cornet, Jean-Louis Camicas, and Gilles Chauvancy.

"Au Hasard" Observations. In Yonofere and Dahra-village, a herd of sheep is chosen by chance encounter, and 10 randomly selected individuals are carefully examined for the presence of ticks. Particular attention is focused on the tail, perianal and abdominal regions, feet and the head (ears and eyes). All ticks are removed with forceps and stored for later identification and virus isolation. We attempt to study 5 herds at each site about every month. Samples were first taken beginning in May and are continuing; to date we have studied more that 500 sheep in this manner. From these animals close to 2000 adult *H. truncatum*, *H. impeltatum*, *H. marginatum rufipes*, *H. dromedarii*, *Rhipicephalus evertsi evertsi*, and *R. guilhoni* have been sampled. Results are still insufficient to draw any conclusions; however, as we continue to amass and analyse observations such as these in the future, we expect to be able to characterize the relative abundances and seasonal pattern of activity of the adult stages of each tick species that infests sheep.

Tick burden and infection rate. A second source of information on adult tick abundance is derived from animals which are regularly bled. At the Dahra-station, cattle that permanently reside there are sampled monthly during periodic captures undertaken by personnel of the station; while these animals are restrained, we search carefully for ectoparasites as described above. Similarly, a subsample of 20 sheep that remains confined to the station is examined each month. We are in the process of describing the seasonal dynamics of ticks on cattle and sheep which are non-migratory and which inhabit another region where CCHFV circulates. Furthermore, the heritage, herd group, date of birth and history of pasture use is known for each individual cow, permitting more detailed analyses as questions arise. Comparable observations of privately-owned sheep and cattle, that forage over a very large area are being made in Dahra-village.

Sentinel Animals. A third source of information on adult tick abundance is coming from privately-owned sheep and cattle in Yonofere and Bandia. These animals have been tagged or are otherwise individually known, but are maintained as the owner wishes. Each individual is examined as described above every month or two. About 20 and 50 sheep are being followed in Bandia and Yonofere, respectively. Such observations permit comparisons with a somewhat different ecological region (Fig. 1). Repeated observations of the same animals allows us to consider individual differences in infestation rates.

Collections "en masse". In order to retrieve large numbers of ticks for virus isolation efforts (described below), herdspeople in the region around Yonofere are provided tubes into which they are asked to collect ticks from their animals. Collections, gathered monthly, are separated by species (sheep, cattle, horses) and owner. Although the collection technique is non-standardized and numerous biases exist that could influence the number and relative frequency of each tick species, we expect to compare these calculations of seasonal activity and host preference with those made from other more systematic collections.

Immature ticks on birds. Observations have begun which are designed to determine the role of birds has hosts to larval and nymphal ticks, and to characterize seasonal activity and densities of hosts and parasite. About monthly, birds are captured or shot at Yonofere and Bandia, using Japanese mist-nets or a 32-gauge shotgun. Each bird is carefully examined by blowing air through a tube to seperate the feathers and thereby view the skin. Attached larvae and nymphs are removed to live vials until molting (thereby facilitating identification), or are stored in 70% ethanol. Organs and blood of killed birds are stored at -70° C. for later study.

Of more than 330 birds examined at Yonofere, 5 (1.5%) harbored ticks, of which all were immature *Hyalomma marginatum rufipes* (15 larvae , 1 nymph) (Table 3). Fewer birds (73) were sampled at Bandia, and 6 (8.2%) were found to harbor 1 larvae and 6 nymphs of this same species of tick (Table 4). The small sample size at present makes generalization difficult, although ground feeding birds seem to be more often infested. Immature *H. marginatum rufipes* and *H. truncatum* appear to commence activity after the beginning of the rainy season (August). Ironically, the paucity of immature ticks that were found feeding on birds may be the most significant result. Although it is much to early to consider our results as yet accurate, it would appear that proportionatly few *Hyalomma* immatures feed on birds. Observations such as these will continue in an effort better describe seasonal activity patterns of larvae and nymphs, infestation rates on bird hosts, as well as the densities of these species.

Immature ticks on small mammals. Small mammals represent the other taxonomic group reputed to serve as host to numerous immature *Hyalomma* ticks. Studies which complement those on birds are ongoing. At Yonofere and Bandia, modified Manufrance live-capture traps, baited with peanutbutter, are placed 10 meters apart in lines located near suitable habitat. Traps are opened at night and emptied the next morning. We utilize traps to produce 120 and 140 trapnights per month at Yonofere and Bandia, respectively. Small mammals are carefully inspected for excoparasites by blowing air across the fur to view the skin surface. Attached ticks are removed with fine forceps and stored in the manner that birds are studied.

The two sites differ both in the number of small mammals captured, and the the intensity of immature tick infestation. At Bandia, 443 small mammals comprising 7 species captured from March through December, 1987 produced 373 ticks of the genera *Hyalomma*, *Rhipicephalus* and *Amblyomma* (Table 5). The vast majority were immature *H. truncatum* (104 larvae, 109 nymphs) and *R. guilhoni* (75 larvae, 85 nymphs). Most (74%) of the small mammals examined were *Mastomys* sp., although the distribution of *H. truncatum* was roughly proportional to capture rates among the various host species. One exception was the hare, *Lepus crawshayi* (*L. whytei* according to some authors) which harbored especially numerous nymphal *H. truncatum*.

At Yonofere, a similar trapping effort from June through December, 1987 produced very different results (Table 6). A total of 62 small mammals were examined; they yielded 71 immature ticks of the genus *Hyalomma*. The most frequently trapped small mammal was *Taterillus sp.*, a rodent not seen at Bandia; *Mastomys* were captured half as often and no *Arvicanthis niloticus* were found. As in Bandia, the few hares that were observed yielded nymphal *H. truncatum*, especially

during November and Decembeer. The seasonal activity for immature *H. truncatum* seems to peak during October through December, particulatly for larvae; nymphs were also found in very small numbers during May through July.

The difference between the two sites in apparent rodent density and immature tick burdens is puzzling. Bandia receives more rain and the vegetation tends to be more dense than at Yonofere. Nevertheless, there appears to be at least as heavy an adult tick burden (particularly *H. truncatum*) on domestic ungulates at Yonofere as at Bandia. How can Yonofere's sparse small mammal population, harboring relatively fewer immature ticks, produce an apparently abundant population of adult ticks? This represents an unresolved question that is fundamental to our understanding of the population dynamics of CCHF vector ticks, and one which will receive increased attention during the next two years.

Drop-off Rhythm of *Hyalomma* species

Immature tick drop-off from rodents. To the extent that birds and small mammals do indeed serve as host to numerous larval and nymphal ticks, the distribution and behavior of these hosts could influence the spatial pattern over which molted nymphs and adults, respectively, would emerge and quest. Numerous studies of the timing of drop-off in Ixodid ticks have demonstrated certain regularities that vary with species. Larvae and nymphs of *Ixodes ricinus*, for example, show the same pattern of drop-off: both stages detach predominantly during the daylight hours (e.g. Graf et al. 1978). This would be at a time when their principal hosts, rodents that exhibit a nocturnal activity pattern, would be resting in their burrows. Alternatively, *Hyalomma excavatum* larvae detach predominanly during the daylight hours, whereas nymphs show the opposite pattern (Hadani and Rachav 1970). Thus, such differences among tick species would influence the ecology of molting and subsequent questing behavior. No other such studies of West African *Hyalomma* species are known. Accordingly, studies designed to address this question have begun in collaboration with Dr. Thomas Logan of USAMRIID.

Larval *H. truncatum*, reared from adults captured in Yonofere were fed in the laboratory on guinea pigs. Between 2000 and 4000 larvae were placed on each of 6 tranquillized guinea pigs: 3 at 1100h and 3 at 2000h on day 1. Each host was held seperately in a cage suspended over a water pan. Engorged ticks which detached were removed and counted every 2 hours during a period of 84 hours, beginning the 3rd day after attachment. Observations were made in a room open to ambient temperature (22-28 °C), and natural illumination (ca. 13.5L:10.5D) during 31 April - 4 May). A total of 4,697 engorged ticks were recovered: 2,499 from group 1 guinea pigs and 2,198 from group 2. More than 80% of ticks dropped off

during days 4 and 5 post-attachment. The pattern of drop-off during this 48 hour period was consistent: most ticks detached during the dark phase of the solar cycle (Fig. 2). Interestingly, there appeared to be a slight "lag" in drop-off of ticks that had been placed on group 2 hosts later in the day (dashed line). Preliminary results such as these suggest the existence of a diurnal pattern of detachment, and that a large porportion of *H. truncatum* larvae may leave their hosts while they are likely to be underground.

Adult tick drop-off from sheep. In a second experiment, again in collaboration with Dr. Logan, we examined the same phenomenon in adult *H. truncatum*. Male and female ticks were removed from sheep in Yonofere and examined microscopically for evidence of host fluids. Those ticks that appeared not to have begun feeding (considered "flat" or unfed) were replaced on sheep housed at the Institut Pasteur. A total of 30 male and 30 female *H. truncatum* were placed on each of 6 sheep, inside a nylon stocking that had been securely fastened to the end of each sheep's tail. Three sheep (group 1) were infested at 1400h and the other three (group 2) at 0200h the next day. They were housed together in an outdoor pen and were checked every 4 hours beginning 5 days after the first group was infested.

Engorged ticks detached from 5 to 9 days post-attachment. From the total of 180 female *Hyalomma truncatum* placed on the 6 sheep, 54 (30%) (range 2-16) engorged, detached and were retrieved. Such a small sample size made analysis difficult. Therefore, the temporal pattern of drop-off of female ticks was analysed for each of the two groups of sheep (Fig. 2) that were infested either at 0200h (solid line) or at 1400h (dashed line). Each data point of Fig. 2 represents the percentage of that group's ticks which detached during that 4-hour period for all 5 days of study. It appears that maximum adult tick drop-off occured during the early daylight hours, then declined toward the middle of the day, and again rose at and just after sunset. The observed pattern was simlar for sheep infested at the two different times. Results such as these suggest a circadian pattern, although further studies are necessary to critically test these preliminary observations.

Rodent burrow excavation. If a substantial number of nymphal ticks detach while their host is underground, these ticks may molt and remain sequestered inside such burrows, awaiting conditions that favor questing. In order to investigate whether engorged larval and nymphal ticks, or unfed nymphal or adult ticks are abundant in such sub-terrainian habitats, we have begun to systematically excavate rodent burrows throughout the seasonal cycle. In collaboration with Drs. Thomas Logan and Jean-Paul Cornet, randomly selected rodent burrows are examined: six new burrows are excavated each month at both the Bandia and Yonofere sites. The burrow entrance is opened with a small shovel and

other such tools, and the losened soil is aspirated by a large "vacume" constructed from a gasoline-powered leaf blower. A series of filters seperates larger rocks but permits fine sand to pass while trapping ticks and other small arthropods. All tunnels and chambers are opened and the contents aspirated. Based on the structure of the burrow, and the size and shape of fecal pellets, the rodent species that inhabits the site is identified.

A total of 84 burrows have been examined during May through December 1987 including those of *Taterillus sp.* (41), *Mastomys sp.* (33), *Arvicanthis niloticus* (5), *Xerus erythropus* (4), and *Erinaceus albiventris* (1). Although about half of these burrows contained the Argasid tick *Ornithodoros sonorai* (sometimes numbering more than 100 per burrow), few Ixodid ticks were recovered. All Ixodids were adults and included 8 *Hyalomma truncatum* (in 6 burrows), 4 *Rhipicephalus guilhoni* (3 burrows) and 1 *Rhipicephalus sulcatus* (1 burrow). The absence of abundant Ixodid adults in rodent burrows suggests either that few nymphal ticks detach therein or that newly molted adults rapidly exit these burrows. The full cycle of seasons has not yet been studied and therefore the behavior of replete, detached immature *Hyalomma* remains unknown. It may be noteworthy that adults of *H. truncatum*, immatures of which typically feed on rodents, were found in the burrows, whereas adult *H. marginatum rufipes*, whose immatures are typically bird parasites, were absent. Investigations are continuing.

Questing Behavior of Ticks

Flagging. The time and place of tick questing depends upon numerous factors including climate, microhabitat, season, host stimuli, etc. Two standard sampling devices have been used both to estimate questing tick abundance independent of host abundance, and to evaluate the sites from which questing occurs. Standard $1m^2$ cloth "drags" and smaller "flags" have been employed in an attempt to attract and "capture" ticks that are resting on vegetation. The material is pulled or pushed through grassy or shrubby vegetation and periodically examined for attached ticks. At our primary study sites, we have been unsuccessful at collecting many adult ticks using this method. However, at another site experiencing an intense infestation of *Hyalomma truncatum* and *H. impeltatum*, flagging was extremely successful; numerous adult ticks were found crawling along the ground and onto the clothing of people who walked through infested grass. Thus, our failure to capture large numbers of adults using the flagging method may reflect sparse populations of ticks or insufficient olfactory or tactile stimuli. These methods are presently being reevaluated and modified.

Using these same flagging methods, we experienced little success in capturing immature ticks. During the fall period

of intense larval *Hyalomma* activity, however, we successfully flagged numerous *H. truncatum* and fewer *H. marginatum rufipes*. Systematic observations will continue.

Carbon Dioxide traps. A second method of tick sampling is being used in an attempt to determine habitats where questing ticks reside. Simple sticky-traps are set with "dry ice" that artificially raises the concentration of atmospheric CO_2 immediately surrounding these traps. Ticks that respond to this stimulus are drawn to the dry ice platform and become stuck to it. This technique has been successful in censusing *Dermacentor* and *Amblyomma* ticks. Preliminary tests indicate that in certain settings, adult Ixodids that we are studying are attracted to this trap: we have thusfar successfully captured *H. impeltatum*, *H. marginatum rufipes*, and *Rhipicephalus evertsi evertsi*. We shall be applying this technique systematically throughout the cycle of seasons.

Tick Reproduction

One important component in the demographic equations that we plan to develop for certain *Hyalomma* ticks involves the reproductive capacity of adults. The "age pyramid" for discrete-stage arthropods has at its base the number of eggs produced by the preceeding generation of females. Studies are underway that should permit us to estimate productivity of ticks and ultimately be useful in calculations of the Basic Reproductive Rate both of ticks and of virus. Female *Hyalomma truncatum*, *H. marginatum rufipes*, *H. impeltatum* and *Rhipicephalus evertsi evertsi* that have been removed from wild hosts are being held in the laboratory for observations. Ticks are initially weighed, and then kept in individual vials stored in incubators maintained at ambient temperature and 85-95% RH until eggs are laid. The timing and magnitude of egg-laying and hatching is recorded. More than 800 ticks of these species have been studied to date. Using these results we are attempting not only to describe various facets of reproduction, but to determine whether infection with CCHFV might influence its timing or success.

Physical Ecology

Standard descriptions of vegetation, climate and geography will help us to compare results from different sites within Senegal, and also these results with observations from other parts of the continent. We are studying, for example, the relative density of major plant associations for regions and microhabitats inhabited by important hosts, certain features of the topography, proximity to standing water, and annual rainfall (from published records). Based upon this information, we shall characterize each tick species in terms of its geophysical associations, and attempt to correlate

virus infection rates with such features. Much of this data is already available and/or regularly monitored. The national "Service Regional de l'Hydraulique" maintains daily records of rainfall from numerous sites throughout northern Senegal. Various studies have thoroughly characterized the geology (e.g. Pierre 1973), vegetation (e.g. Bille 1971) and land-use patterns (e.g. Barral 1982) of the region. Thus, abundant information already has been identified and we are presently organizing this into a data base useful to our project.

II. VERTEBRATE-VIRUS INTERACTIONS

Information on "host associations" or on the magnitude of ectoparasite infestation is necessary but insufficient for understanding the transmission dynamics of a vector-borne pathogen. Differences in the population densities of various hosts, for example, would alter the significance of a given level of infestation. Similarly, the efficiency of transmission, host inhibition of vector feeding, or pathogen effects on host or vector demography could effect the interactions that ultimately form the conditions of transmission. In collaborative studies with Drs. Jean-Louis Camicas and Jean-Paul Cornet, we have made progress in gathering observations relating to these variables.

Host Population Densities

The density of vertebrate hosts may amplyfy or diminish the population significance of vector infestation or parasite infection. Therefore, we seek knowledge of host abundance and distribution in an attempt to understand the population interactions among hosts, parasites, and pathogens. Accordingly, we have begun to estimate vertebrate host densities at our primary study sites using various direct and indirect measures. Rodent densities are being estimated from line-transect trapping and capture-recapture statistics (e.g. Southwood 1978). Domestic ungulate density estimates are complicated by complex movement patterns and heterogeneous distribution (Barral 1982), but local densities will be estimated from village censuses and personal counts. Numerous studies of the avifauna have demonstrated annual fluctuations in bird species densities (e.g. Morel and Morel 1972), often dependent upon rainfall. Although complicated by such annual variability, estimates made by other workers such as these will be used for those species whose tick burden is slight, as they contribute little to the population of feeding ticks. Such calculations of host density will be combined with estimates of tick burden and infection rates in order to estimate the relative contribution of each host to virus transmission.

Prevalence of Infection in Ticks

A major objective of our project is to characterize the magnitude of infection in vectors and hosts in order to aid in calculations of transmission potential. To this end we have been collecting feeding ticks which are analysed for the presence of CCHFV infection. Three types of collections are being made.

Collections "en masse". Numerous ticks are being collected monthly for virus isolation by herdspeople in Yonofere and surrounding villages who are given tubes into which they place ticks removed from their cattle, sheep, goats, horses, donkeys and camels. The collections, separated by host species and owner (or encampment), are then pooled by tick species. From these animals more than 10,000 *Hyalomma truncatum*, *H. impeltatum*, *H. marginatum rufipes*, *H. dromedarii*, *Rhipicephalus evertsi evertsi*, and *R. guilhoni* thusfar have been sampled. Pooled ticks are held at -70°C until testing, at which time they are ground for virus isolation. In collaboration with Dr. Bernard LeGuenno and personnel of USAMRIID's Disease Assessment Division, an antigen-capture ELISA is being used to test for presence of CCHFV. Verification of ELISA-positive ticks or eggs testing shall be made following mouse passage using a CF test. Of more than 2,000 pools collected, 629 have been tested and 23 have produced arboviruses. All but 5 of these have proven to be Wad-Manani virus, and the identity of 6 others has not yet been ascertained.

"Au Hasard" Sheep. In Yonofere and Dahra-village, randomly selected herds of sheep are being studied for tick burden and seasonal activity (described above); these ticks are also being tested for CCHFV. Tick infection rates in relation to host infestation rates will be characterized in an effort to determine the manner in which these variables interact.

Tick and host infection rates. Another source of material for calculating tick infection comes from those hosts also being bled for evidence of anti-CCHFV antibodies. As described above, individually-marked cattle and sheep at Bandia, Dahra-station and Yonofere are examined for ticks and bled monthly. Ticks are being held and tested as above. Host sera are also being tested (described below) and correlations are being attempted.

Prevalence of Infection in Vertebrates

To obtain estimates of the prevalence of CCHFV infection in vertebrates, blood and tissue samples are being obtained at all three main study sites. In addition, samples are

occasionally made at other sites throughout Senegal, Mauritania, Mali, and The Gambia. Blood samples are taken from not only domestic animals, primarily sheep and cattle and goats, but also from birds, small mammals, dogs and other vertebrates. (Organs are also sampled from animals that are killed or die.) Blood is allowed to clot and then held at +5-10°C for 1-4 days after which the serum is removed and stored at -70°C. A CCHFV-antibody capture ELISA is being used by Dr. LeGuenno and USAMRIID colleagues to test ungulate sera. A similar test is being developed for other species.

A portion of the sera thusfar collected have been tested and results demonstrate the presence of infected ungulates in the study sites. Of 381 sheep and cattle sera tested, 52 (13.9%) are positive with anti-CCHFV IgG antibodies (Table 7). It is too early to suggest that sites or species differ in their prevalence of infection. Curiously, numerous cattle at the Dahra-station site were infected, whereas none of those studied in Dahra-village tested positive. Similarly interesting was a group of 20 female cattle and their 2-4 month-old offspring at the Dahra-station; 80% of the mothers and 60% of the calves expressed IgG antibodies suggesting either a focus of infection in an area where these cattle grazed, and/or transplacental or milk-borne transmission of antibodies to the calves. More detailed analyses will be undertaken to explore observations such as these.

A second source of information on prevalence comes from stored ungulate sera that had been previously collected in other regions. In collaboration with various agencies and researchers, samples are being tested from numerous regions in Senegal, The Gambia and Mauritania. Preliminary results demonstrate a similar prevalence of infection as that found at our Ferlo study sites, although detailed analyses are only beginning. For example, from among 508 sheep sera recently collected by Dr. Philipe Christie of the Mauritanian "Service National D'Elevage et de Recherches Veterinaires" in southern Mauritania, we found an IgG anti-CCHFV antibody prevalance of 10.6%. Similarly, of 136 sheep sera recently collected in The Gambia in collaboration with Drs. C. J. Peters and Thomas Ksiazek of USAMRIID, and personnel of the Gambian Ministry of Health and the Ministry of Animal Health and Production, 15 (11%) expressed IgG antibodies. We will be expanding our observations to include banked sera from other regions, and a more detailed epidemiological analysis of CCHFV infection.

Incidence of Infection in Sheep

In an attempt to describe the incidence of new CCHFV infection aquired under natural conditions, and ultimately relate this to the seasonal dynamics of various *Hyalomma* species, we are periodically monitoring a group of individually-identified, privately-owned sheep in Yonofere.

Numbered eartags (Allflex Europe S.A.) have been placed on about 70 sheep to date, though many of those tagged earlier died in a short period during August, 1987. The difficulties of such an effort are well known, but the events surrounding this particular widespread and sudden mortality are noteworthy.

On 6 June 1987, 48 sheep from 3 small herds were eartagged, bled and examined for ectoparasites. They were seen again on 8 July at which time 45 remained (3 had been sold). The group was next visited on 9 September; of the original 45 sheep, 19 (42%) had died during the month of August, leaving 26 sheep remaining. These were then rexamined 2 months later (4 December) and an additional 3 had died and one was missing. Of the 22 remaining sheep, we later found 18 during a return visit on 4 February, 1988. Thus, an average monthly loss rate of from 5-7% occured during September through February, as compared with the death of more than one third of sheep during the month of August. Suspecting that the epidemic of Rift Valley Fever (RFV) which was sweeping the Senegal River Basin 100km to the north had perhaps included our study area, sera from the surviving sheep sampled during September 1987, December 1987, and February 1988 were tested for anti-RVF virus (RVFV) antibodies. From 26 sheep tested in September, 2 (7.7%) had IgM antibodies and 6 (23.6%) had IgG antibodies. The prevalence of RVFV antibodies among 22 of the same sheep that remained in Deceber increased: 9 (40.9%) IgM positive and 18 (81.8%) IgG positive. In February 1988, none of the 17 sheep tested expressed IgM antibodies while 13 (76.5%) continued to test IgG positive. Furthermore, the rate at which sheep were "lost" from the study also differed with IgM status. The combined rate of sheep disappearance (which we presume occured due to death) during the September-December and the December-February intervals was 46% (5 of 11) of IgM-positive sheep, versus only 13.9% (5 of 31) of IgM-negative sheep. These results stongly suggest that a RVF epidemic also occured at the Yonofere study site. Although not directly relevant to our studies of CCHF tranmission, it is nevertheless an interesting result coincident with these studies.

The incidence of CCHFV infections during this period appears to be low, however due to the deaths of numerous previously sampled sheep, it was difficult to calculate. Of 22 and 17 sheep tested during September 1987 and February 1988, 2 were IgG-positive against CCHFV; no new sero-conversions were found during this 5 month period. We are presently ear-tagging new animals that will be monitored every two months in this ongoing effort.

III. VIRUS TRANSMISSION

Transovarial Transmission

Numerous arboviruses are known to be transmitted "vertically" directly from one arthropod generation to the next without passing "horizontally" through a vertebrate host. Circumstantial evidence suggests that such transovarial transmission (TOT) occurs for CCHFV in nature: few vertebrates express intense or sustained viremia and certain tick species have been shown capable of TOT in laboratory tests. To investigate the relative importance of vertical versus horizontal transmission, we have begun observations designed to determine the TOT rate for CCHFV in northern Senegal. Feeding ticks are removed from cattle, sheep and camels in our study sites and placed in individual vials in the laboratory as described above. Following egg-laying, the adult tick's corpse is frozen at -70°C, as are a portion of the eggs. Using the ELISA test mentioned above, we are testing for the presence of CCHFV in both the parent tick and its eggs. Verification of ELISA-positive ticks or eggs testing will be made following mouse passage using a Complement Fixation test. Furthermore, we are attempting to use larvae that emerge from CCHFV-infected egg batches to calculate the percentage of eggs infected transovarially, and to determine if transstadial transmission of TOT infected eggs occurs. More than 800 ticks comprising 4 species of *Hyalomma* and 2 species of *Rhipicephalus* thusfar have been returned to the laboratory in this ongoing effort; analysis has just recently begun.

Horizontal Transmission

The capacity of a vector to transmit a particular pathogen depends upon variables such as frequency of vector feeding, time between blood-meals, diversity of host species utilized, extrinsic incubation time for the pathogen, and efficiency of pathogen transmission to the host. A multitude of complementory factors influence the hosts ability to reinfect the vector. Certain of these components can be studied under field conditions, and we have begun observations to this end.

Results from observations on tick infestation rates, infection rates of these ticks, and serology of their hosts will be examined as an ensemble in an attempt to correlate differences in rates of infection that might explain intensity of transmission. Analyses such as these will guide subsequent experimental studies that we plan for the latter part of the project. It appears that CCHF virus may be maintained at a low level of enzootic transmission, in quiescent foci around which human infection occurs sporadically. These foci would

be characterized by a close association between particular reservoir hosts (or conditions of TOT) and the ticks that parasitize that population. Human infection might result solely when exceptional conditions occur: for example, environmental change that diverts vector feeding from typical vertebrate hosts to humans, unusual contact with vector ticks in a habitat that has a paucity of vertebrate hosts, or a suddenly increased abundance of vector-competent ticks that feed indiscriminantly. By developing simple mathematical models which describe the vector competence of ticks, rates of host infection, immunity and loss of immunity, and demographic patterns of hosts and ticks, we shall attempt to synthesize our observations into a more meaningful, perhaps predictive whole.

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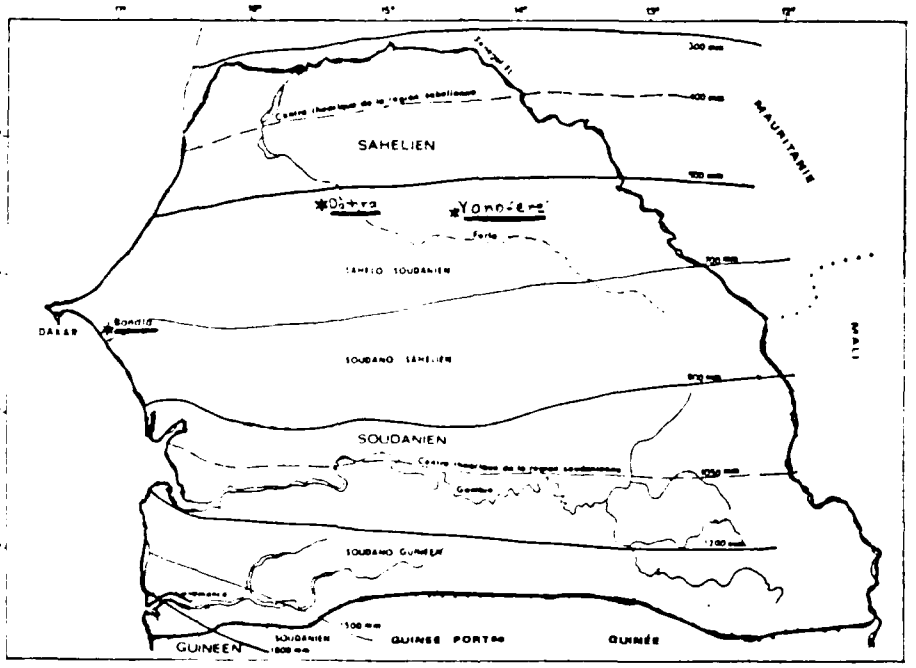
Figure 1. Maps of Senegal, illustrating the locations of the principal study sites of Bandia, Dahra and Yonofere, as well as geoclimatic features, and the distribution of ticks (from Camicas et al. 1986).



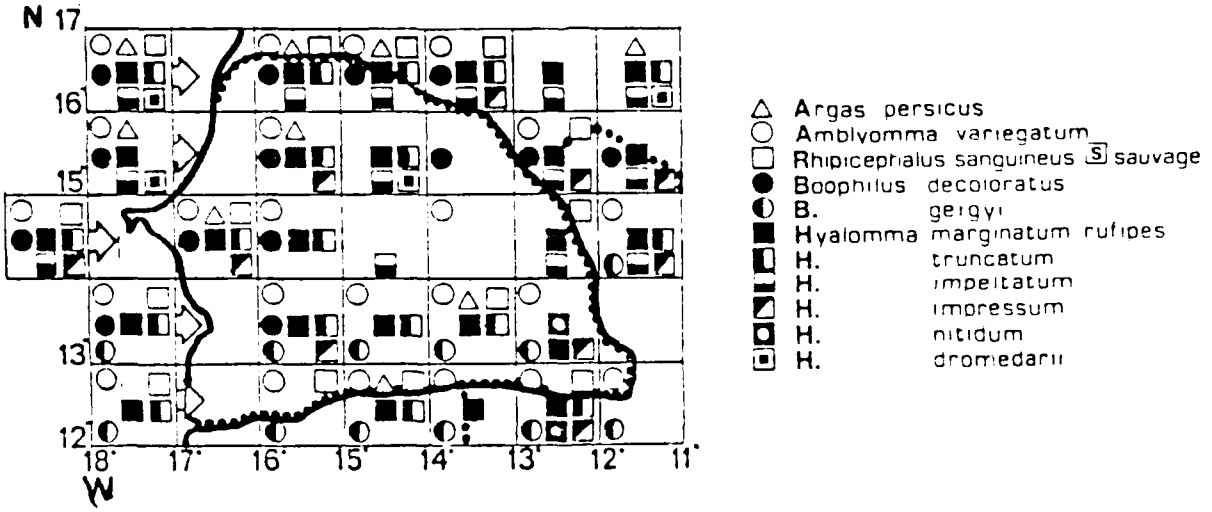


Figure 2. Temporal distribution of dropoff of larval *Hyalomma truncatum* from two groups of guinea pigs infested at 1100h (solid line) or at 2000h (dashed line). Each point represents the percentage of all ticks from that group which detached during that 2 hour period.

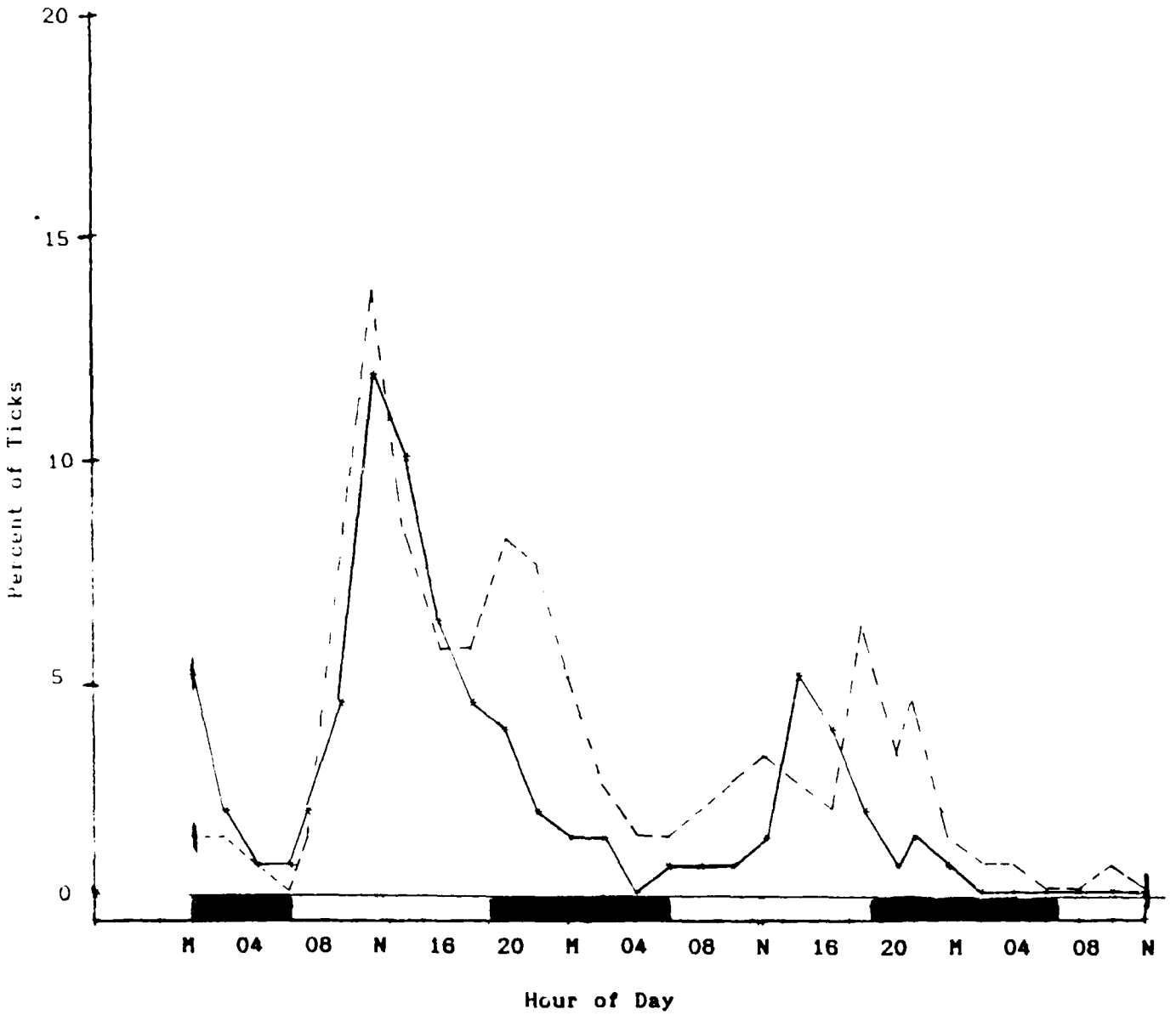


Figure 3. Temporal distribution of dropoff of female *Hyalomma truncatum* from two groups of 3 sheep each, infested either at 0200h (solid line) or at 1400h (dashed line). Each point represents the percentage of that group's ticks which detached during that 4-hour period for all 5 days of study. Each point is displayed in the middle of the 4-hour period it summerizes.

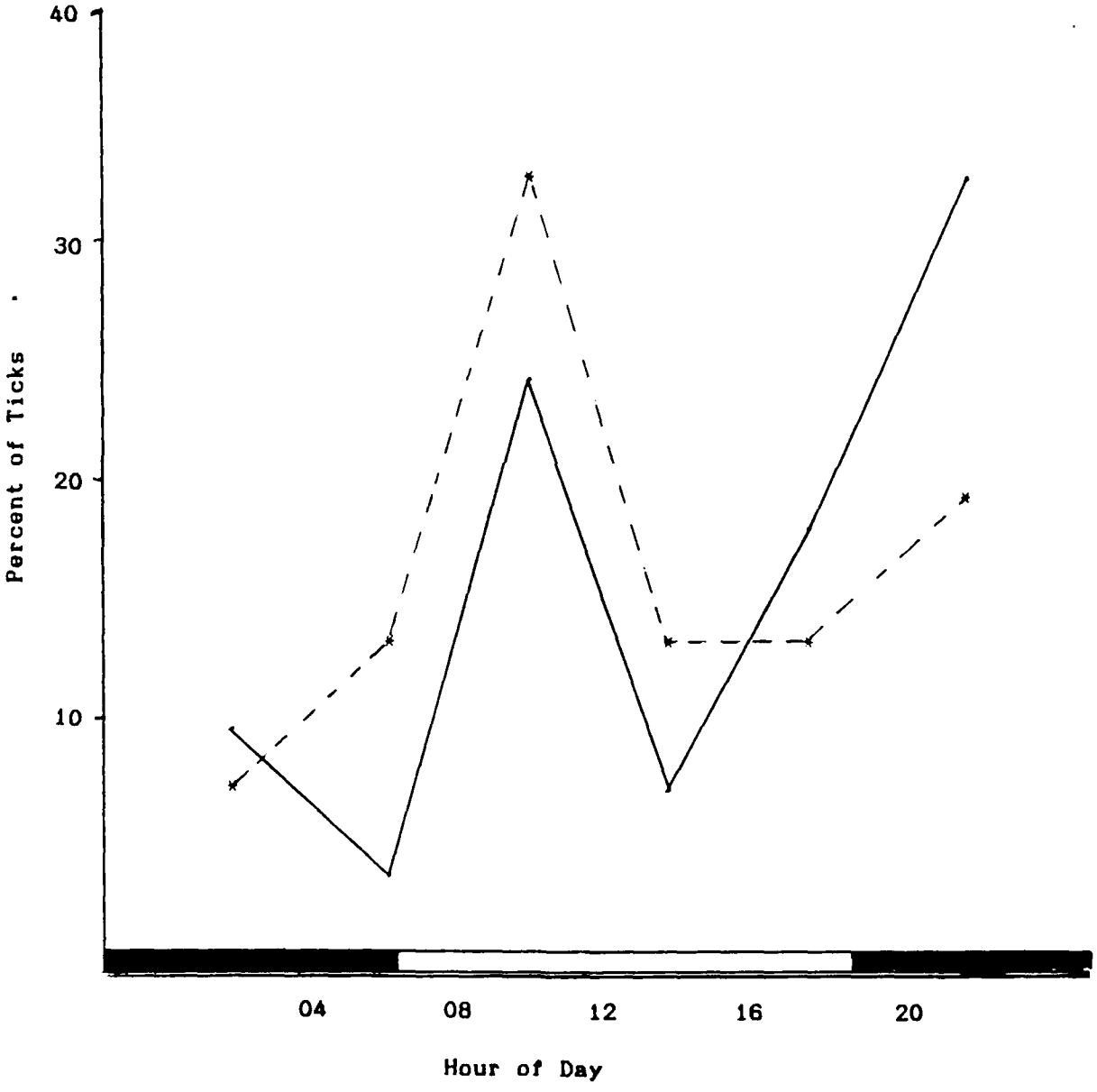


Table 1. Additional personnel who have participated in the studies presented in this report.

Camicas, Jean-Louis Cornet, Jean-Paul	Laboratoire ORSTOM de Zoologie medicale, Institut Pasteur de Dakar
Jouan, Alain Le Guenno, Bernard Ndiaye, Magueye Saluzzo, Jean-Francois	Institut Pasteur, Service d'Ecologie Virale, et Laboratoires de Biochimie et Virologie Fondamentale
Calvo, Marie-Armande	Institut Pasteur, O.M.S Centre de Reference et de Recherche sur les Arbovirus
Ba, Kalilou Chauvancy, Gilles	ORSTOM, Laboratoire de Zoologie
Diouf, Abdoulaye Gueye, Arona Sarr, Antoine Sow, Racine	ISRA, Laboratoire National de l'Elevage et de Recherches Veterinaires
Ksiazek, Thomas G. Logan, Thomas M. Meegan, James M. Peters, C. J.	USAMRIID, Division of Disease Assesment, Departments of Immunology and Arboviral Entomology

Table 2. Summary of research progress and planning during 1987 for studies on the ecology and epidemiology of Crimean-Congo Hemorrhagic Fever in Senegal.

Topical Question	Stage[1] &/or Host	Proposal Section	Month[2] began at Site[3]: Y	D	B	M	P
		I. TICK ECOLOGY and BEHAVIOR					
A. Host Association	A, Dom. Ungul.	3,5a	3		1	4	
	LN, Birds/Sm. Mamm	3,5a	3		1	4	
B. Seasonal Activity	A, Sheep	5b,5d	5	5	1		
	LN, Birds/Sm. Mamm	5b,5d	3		1		
C. Drop-off Rhythm	A, Sheep	New					4
	LN, Rodents	New					4
	LN, Rodent (burrows)	New	5		5		
D. Questing Behavior	LN, artificial/Rodent	New					F
	LN, flagging	New	4		5		
	LNA, CO_2	New	4	10		F	
E. Survival Rates	Unfed LN	New					5
	Fed A	New	F		F		F
F. Reproducion	Engorged A	New	3	5		1	1
G. Physical Ecology	LNA, Humans, Vertebr.	4	1	1	1		
		II. VERTEBRATE-VIRUS INTERACTIONS					
A. Popul. Density	Ungul., Rodent, Bird	5c	3		1		
B. Infection Preval.	Domestic Ungulates		3	4	1	1	
	Rodents & Birds		3		1		
	Humans	6	F		F	F	
C. Infection Incid.	Sheep		6				
		III. VIRUS TRANSMISSION					
A. Infection Preval.	A, Dom. Ungulates	7	3	6		3	
B. Transovar. Trans.	Engorged A	7				3	4
C. Horizontal Trans.	LN, Rodents / A, Sheep	7	3		1		
D. Lab. Xenodiagnosis	LN, Rodents	9					F

1. Ticks include *Hyalomma truncatum, H. impeltatum, H. marginatum rufipes,* and *Rhipicephalus guilhoni. Stages are: L = Larvae, N = Nymphs, A = Adults*
2. Months are: 1 = Jan., 2 = Feb., etc.; F indicates Future study planned.
3. Sites are indicated by Y = Yonofere, D = Dahar, B = Bandia, P = Pasteur Laboratory, and M = Miscellaneous sites.

Table 3. Monthly observations of birds and attached immature *Hyalomma marginatum rufipes* during March - December, 1987 in Yonofere, Senegal.

Bird Species[1]	Mean No. ticks on (N) birds during:										
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mar-Dec
Francolinus bicalcartus (Double-spurred Francolin)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (1)	- (0)	- (0)	0 (1)	0 (2)
Ptilopachus petrosus (Stone-partridge)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (2)	- (0)	0 (2)
Eupodotis senegalensis (Senegal Bustard)	- (0)	- (0)	- (0)	- (0)	0 (5)	0 (2)	- (0)	- (0)	0 (2)	- (0)	0 (9)
Eupodotis melanogaster (Black-bellied Bustard)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (1)	0 (2)	0 (1)	- (0)	- (0)	0 (4)
Columba guinea (Speckled Pigeon)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (3)	0 (3)
Streptopelia senegalensis (Laughing Dove)	0 (5)	0 (3)	0 (4)	0 (5)	0 (6)	0 (4)	0 (6)	0 (7)	0 (7)	0 (3)	0 (50)
Oena capensis (Long-tailed Dove)	0 (8)	- (0)	- (0)	0 (1)	0 (2)	- (0)	- (0)	0 (4)	- (0)	- (0)	0 (15)
Vanellus tectus (Black-headed Plover)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (1)	- (0)	- (0)	0 (2)	0 (3)
Vanellus spinosus (Spur-winged Plover)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (3)	- (0)	- (0)	- (0)	- (0)	0 (3)
Pterocles exustus (Chestnut Sand-grouse)	0 (3)	0 (8)	0 (7)	- (0)	0 (3)	- (0)	- (0)	0 (2)	0 (7)	0 (4)	0 (34)
Pterocles quadricintus (Four-banded Sand-grouse)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (3)	0 (3)	- (0)	- (0)	0 (6)
Coracias abyssinica (Abyssinian Roller)	- (0)	- (0)	- (0)	0 (3)	0 (1)	- (0)	0 (1)	0 (1)	- (0)	- (0)	0 (6)
Merops albicollis (White-throated Bee-eater)	- (0)	- (0)	- (0)	0 (2)	- (0)	0 (1)	0 (1)	- (0)	- (0)	- (0)	0 (4)
Caprimulgus climacurus (Long-tailed Nightjar)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (2)	- (0)	- (0)	0 (2)

Continued.....

Table 3. Continued.

Bird Species	Mean No. ticks on (N) birds during: Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mar-Dec
Macrodipteryx longipennis (Standard-winged Nightjar)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (3)	- (0)	- (0)	0 (3)
Tockus erythrorhynchus (Red-beaked Hornbill)	0 (1)	0 (2)	0 (5)	- (0)	0 (2)	- (0)	0 (1)	0 (1)	0 (1)	0 (1)	0 (14)
Spreo pulcher (Chestnut-bellied Starling)	0 (1)	0 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (2)	0 (3)	0 (0)	0 (7)
Serinus mozambicus (Yellow-fronted Canary)	- (0)	- (0)	- (0)	- (0)	0 (2)	- (0)	- (0)	0.3L (3)	- (0)	- (0)	0.2L (5)
Ploceus luteolus (Slender-billed Weaver)	- (0)	- (0)	- (0)	- (0)	- (0)	0.5L (2)	- (0)	0 (1)	- (0)	- (0)	0.3L (3)
Ploceus vetellinus (Vitelline Masked Weaver)	- (0)	0 (4)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (4)	0 (1)	- (0)	0 (9)
Ploceus cucullatus (Village Weaver)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (3)	0 (9)	- (0)	- (0)	0 (12)
Sporopipes frontalis (Scaly-fronted Weaver)	0 (1)	- (0)	- (0)	0 (1)	- (0)	- (0)	0 (1)	0 (1)	- (0)	- (0)	0 (4)
Passer griseus (Grey-headed Sparrow)	0 (1)	0.8L (13)	0 (4)	0 (6)	0.3N (4)	- (0)	- (0)	0 (4)	0 (5)	0.6L (5)	0.3LN (42)
Amadina fasciata (Cut-throat Weaver)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (4)	0 (3)	- (0)	- (0)	0 (7)
Lagonosticta senegala (Senegal Fire-finch)	0 (10)	0 (30)	0 (10)	0 (2)	0 (2)	0 (2)	0 (1)	0 (2)	0 (5)	0 (8)	0 (72)
TOTAL	0 (30)	0.2L (61)	0 (30)	0 (20)	<0.1N (27)	0.1L (15)	0 (25)	0 (53)	<<0.1L (33)	0.1L (27)	<<0.1LN (321)

1. Additional birds captured solely on one occasion, and which harbored no ticks include: *Prinia subflava*, *Jynx torquilla*, *Lamprotornis splendidus*, *Buphagus africanus*, *Oenathe hispanica*, *Myrmecocichla cinnamomeiventris*, *Cercotrichas podobe*, *Phylloscopus trochilus*, *Nectarinia chloropygia*, *Upupa epops*, *Serinus leucopygius*, and *Estrilda bengala*.

Table 4. Monthly observations of birds and attached immature *Hyalomma marginatum rufipes* during April - December, 1987 in Bandia, Senegal.

Bird Species	Mean No. ticks on (N) birds during: Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Apr-Dec
Streptopelia senegalensis (Laughing Dove)	0 (2)	0 (2)	0.5N (2)	0 (4)	0 (3)	0.5L (2)	- (0)	0 (1)	- (0)	0.25LN (16)
Oena capensis (Long-tailed Dove)	- (0)	0 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (2)	- (0)	0 (3)
Psitacula krameri (Long-tailed Parrakeet)	- (0)	- (1)	- (0)	- (0)	0 (2)	- (0)	- (0)	- (0)	- (0)	0 (2)
Halcyon senegalensis (Senegal Kingfisher)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (1)	- (0)	- (0)	- (0)	0 (1)
Eurystomus glaucurus (Broad Billed Roller)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (1)	- (0)	- (0)	- (0)	0 (1)
Upupa epops (Hoopoe)	- (0)	- (0)	- (0)	0 (1)	0 (1)	0 (1)	- (0)	- (0)	- (0)	0 (3)
Tockus erythrorhynchus (Red-beaked Hornbill)	0 (1)	0 (2)	0 (2)	0 (1)	0 (1)	0 (2)	- (0)	0.25N (4)	- (0)	<0.1N (13)
Tockus nasutus (Grey Hornbill)	- (0)	- (0)	- (0)	- (0)	0 (1)	0 (1)	- (0)	0 (1)	- (0)	0 (3)
Ploceus cucullatus (Village Weaver)	0 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (3)
Passer luteus (Golden Sparrow)	0 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (3)
Lamprotornis purpureus (Purple Glossy Starling)	- (0)	- (0)	- (0)	- (0)	0 (1)	0.25N (4)	- (0)	- (0)	- (0)	0.2N (5)
Lamprotornis caudatus (Long-Tailed Starling)	0 (2)	0 (1)	0 (2)	0 (3)	1N (1)	1.0N (2)	- (0)	0 (2)	- (0)	0.25N (12)
Bubalornis albirostris (Buffalo Weaver)	0 (2)	0 (2)	0 (2)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	0 (6)
TOTAL	0 (13)	0 (8)	0.1N (8)	0 (9)	0.1N (10)	0.3LN (15)	- (0)	0.1N (10)	- (0)	0.1LN (73)

Table 5. Monthly observations of immature Ixodid ticks found on small mammals examined during March - December, 1987 in Bandia, Senegal.

Mammal Species[1]	Tick Sp.[2]	Stage	Mean No. ticks on (N) mammals during: Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Mar-Nov
Mastomys	*H. trun.*	L	0	0	0	0	0	0	0	5.1	0	0.2
sp.[3]		N	<0.1	0	<0.1	0	0	0	0	0	0	<<0.1
	R. gui.	L	0	0	<0.1	0	0	0	0	4.6	0	0.2
		N	0	<<0.1	0	0	0	0	0	0.1	0	<<0.1
			(63)	(78)	(44)	(29)	(23)	(35)	(5)	(15)	(32)	(324)
Arvicanthis	*H. trun.*	L	0	0	0	0	0	0	-	3.7	0	0.2
niloticus		N	0	0.2	0	0	0	0	-	0	4.5	0.8
	R. gui.	L	0	0	0	0	0	0	-	1.7	0	0.1
		N	3.8	0	0	0	0	0	-	0.7	5.0	1.2
	A. var.	L	0	0	0	0	0	0.1	-	0	0	<<0.1
		N	0	0	0	0	0	0	-	0	0	0
			(4)	(9)	(3)	(7)	(12)	(8)	(0)	(3)	(10)	(56)
Taterillus	*H. trun.*	L	0	0	0.5	0	0	0	0	-	-	0.2
sp.[3]		N	0	0	0	0	0	0	0	-	-	0
			(1)	(11)	(18)	(8)	(3)	(3)	(3)	(0)	(0)	(47)
Tatera	*H. trun.*	L	-	-	-	-	-	-	-	6	-	6
gambiana		N	-	-	-	-	-	-	-	0	-	0
			(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1)	(0)	(1)
Lepus	*H. trun.*	L	-	0	0	0	0	0	-	0	2	0.2
crawshayi		N	-	0	2.0	4.5	0	0.5	-	43	0	4.8
	H. ruf.	L	-	0	0	0	0	0	-	0	0	0
		N	-	0	0	0	0	1.0	-	3	0	0.4
	R. gui.	L	-	0	0	0	0	0	-	0	0	0
		N	-	0	5.5	0	0	0	-	0	0	0.9
		A	-	0	0	0	0.5	1.0	-	0	0	0.3
			(0)	(2)	(2)	(2)	(2)	(2)	(0)	(1)	(1)	(12)
TOTAL	*H. trun.*	L	0	0	0.1	0	0	0	0	4.7	<0.1	0.2
		N	0	0	0.1	0.2	0	<0.1	0	2.2	1.0	0.2
	H. ruf.	L	0	0	0	0	0	0	0	0	0	0
		N	0	0	0	0	0	<0.1	0	0	0	<<0.1
	R. gui.	L	0	<<0.1	<<0.1	0	0	0	0	3.0	0	0.2
		N	0.2	0	0	0	0	0	0	0.2	1.2	0.2
		A	0	0	0	0	<<0.1	<<0.1	0	0	0	<<0.1
	A. var.	L	0	0	0	0	<<0.1	0	0	0	0	<<0.1
		N	0	0	0	0	0	0	0	0	0	0
			(68)	(100)	(67)	(46)	(40)	(48)	(8)	(20)	(43)	(440)

1. Two *Myomys daltoni* (September) and 1 *Crocidura* sp. (October) harbored no ticks.
2. Tick species are *Hyalomma truncatum*, *H. marginatum rufipes*, *Rhipicephalus guilhoni* and *Amblyomma varigatum*.
3. Locally, the species within the genera *Mastomys* and *Taterillus* are visually indistinguishable. *M. erythroleucus* is more common than the conspecific *M. huberti*; *T. pygargus* and *T. gracilis* are both encountered at this site.

Table 6. Monthly observations of immature ticks found on small mammals examined during June through December, 1987 in Yonofere, Senegal.

Mammal Species	Tick Sp.[1]	Stage	Mean No. ticks on (N) mammals during: Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jun-Dec
Mastomys sp.[2]			0	0	0	0	0	0	0	0
			(6)	(1)	(2)	(1)	(2)	(4)	(1)	(17)
Taterillus sp[2]	*H. trun.*	L	0	0	0.1	0	-	0	0	0.1
		N	0	0.5	0	0	-	2.0	0	0.3
	H. ruf.	L	0	0	0.2	0	-	0	0	0.1
		N	0	0	0	0	-	0	0	0
			(1)	(2)	(18)	(4)	(0)	(4)	(3)	(32)
Xerus erythropus	*Hae. hou.*	M	-	-	0	-	-	3	0	1.0
		F	-	-	0	-	-	1	0	0.1
			(0)	(0)	(1)	(0)	(0)	(1)	(1)	(3)
Desmodilliscus braueri			-	-	0	-	-	-	-	0
			(0)	(0)	(2)	(0)	(0)	(0)	(0)	(2)
Nanomys sp.			-	-	0	-	-	-	-	0
			(0)	(0)	(2)	(0)	(0)	(0)	(0)	(2)
Lepus crawshawi	*H. trun.*	L	-	-	0	-	0	0	0	0
		N	-	-	0	-	0	22.5	5.0	6.4
	H. ruf.	L	-	-	0	-	0	0	0.3	0.1
		N	-	-	0	-	0	0	0.7	0.3
			(0)	(0)	(1)	(0)	(1)	(2)	(3)	(7)
TOTAL	*H. trun.*	L	0	0	<0.1	0	0	0	0	<<0.1
		N	0	0.3	0	0	0	4.7	2.1	1.1
	H. ruf.	L	0	0	0.1	0	0	0	0.1	<0.1
		N	0	0	0	0	0	0	0.3	<0.1
			(7)	(3)	(26)	(5)	(3)	(11)	(7)	(62)

1. Tick species are *Hyalomma truncatum*, *H. marginatum rufipes*, and *Haemophysalis houyi*.
2. Locally, the species within the genera *Mastomys* and *Taterillus* are visually indistinguishable. *M. erythrolecus* is more common than the conspecific *M. huberti*; *T. pygargus* is more often encountered at this site than *T. gracilis*.

Table 7. Prevalence of IgG antibodies against CCHF virus among cattle and sheep at Dahra and Yonofere, Senegal during 1987.

	IgG positive hosts among (N) sampled at:											
Host	Dahra-Station			Dahra-Village			Yonofere			TOTAL		
Species	N	Pos.	%	N	Pos.	%	N	Pos.	%	N	Pos.	%
Sheep	150	20	13.3%	83	4	4.8%	26	2	7.7%	259	26	10.0%
Cattle	94	27	28.7%	28	0	0%	0	-	-	122	27	22.1%
TOTAL	244	47	19.3%	111	4	3.6%	26	2	7.7%	381	53	13.9%